Ohio River Basin Precipitation Frequency Project

Update of *Technical Paper No. 40, NWS HYDRO-35* and *Technical Paper No. 49*

Sixteenth Progress Report
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Hydrometeorological Design Studies Center
Hydrology Laboratory

Office of Hydrologic Development
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1. Introduction

The Hydrometeorological Design Studies Center (HDSC), Hydrology Laboratory, Office of Hydrologic Development, U.S. National Weather Service is updating its precipitation frequency estimates for the Ohio River Basin and surrounding states. Current precipitation frequency estimates for this area are contained in *Technical Paper No. 40* "Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years" (Hershfield 1961), *NWS HYDRO-35* "Five- to 60-minute precipitation frequency for the eastern and central United States" (Frederick et al 1977) and *Technical Paper No. 49* "Two- to ten-day precipitation for return periods of 2 to 100 years in the contiguous United States" (Miller et al 1964). The new project includes collecting data and performing quality control, compiling and formatting datasets for analyses, selecting applicable frequency distributions and fitting techniques, analyzing data, mapping and preparing reports and other documentation.

The project will determine annual all-season precipitation frequencies for durations from 5 minutes to 60 days, for return periods from 2 to 1000 years. The project will review and process all appropriate rainfall data for the project area and use accepted statistical methods. The project results will be published as a Volume of NOAA Atlas 14 on the Internet with the additional ability to download digital files.

The project will produce estimates for 13 states. Parts of nine additional bordering states are included to ensure continuity across state borders. The core and border areas, as well as daily and hourly regions now used in the analysis, are shown in Figures 1 and 2.

Figure 1. Ohio River Basin project area and 80 daily regional groups.

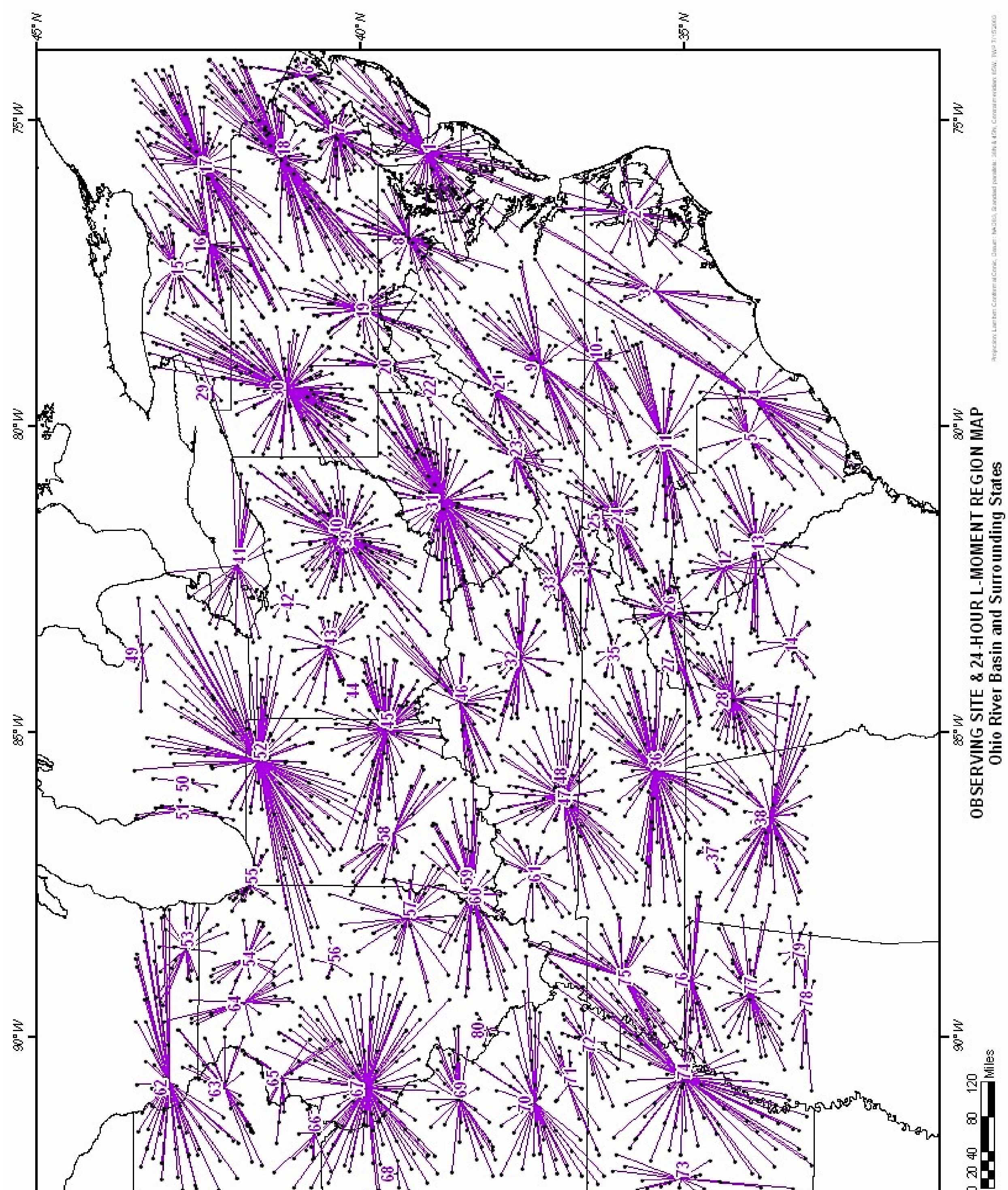
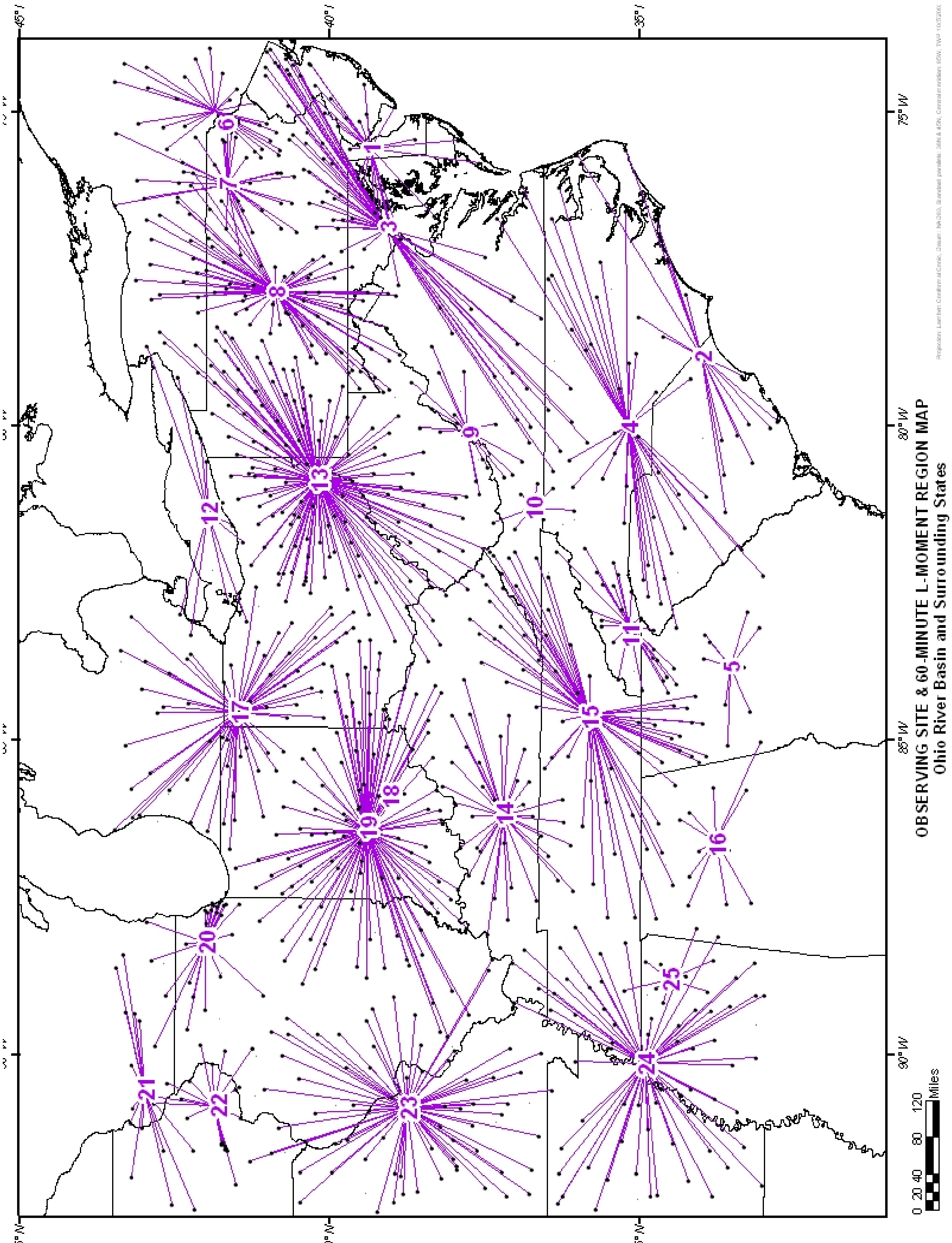


Figure 2. Ohio River Basin project area and 25 hourly regional groups.



2. Highlights

The peer review of point and spatially interpolated precipitation frequency estimates has ended. There were 53 unique comments from 27 individuals or groups that required a response. Additional information is provided in Section 3.1, Peer Review.

Inconsistencies from one duration to the next in a given year were observed in the annual maximum series for some stations. Therefore, an annual maximum consistency check will be conducted as an added QC procedure. Additional information is provided in Section 3.2, Data Quality Control.

The 80 daily regions were checked for longer duration (2-day to 60-day) heterogeneity. The 60-minute regionalization was completed yielding 25 hourly regions (figure 2). The 25 hourly regions were checked for shorter duration (2-hour to 12-hour) heterogeneity. Additional information is provided in Section 3.3, L-moment Analysis.

Best-fitting distributions for daily regions and at-sites were selected based on sensitivity testing results. Best-fitting distributions for hourly regions were also selected. Additional information is provided in Section 3.4, Best-Fitting Distributions.

Software that automates the co-located adjustment procedure was modified to accommodate the use of different distributions for different regions. Additional software was written to accommodate different n-minute ratios for the 2 general n-minute regions of the Ohio project area (northern and southern); to apply the appropriate ratio when populating the PFDS to convert 60-min estimates at hourly stations to n-minute estimates; and to conduct an annual maximum consistency check and adjustment. Software was also developed to check for intersite dependence. Additional information is provided in Section 3.5, Software Updates.

Draft 100-year 24-hour grid and 100-year 60-minute cartographic maps were created for each state. Additional information is provided in Section 3.6, Spatial Interpolation.

The Precipitation Frequency Data Server (PFDS) underwent a few modifications in our continuing effort to make it as user friendly as possible. State-specific password protected web pages were developed to allow peer reviewers to evaluate the draft precipitation frequency estimates for the Ohio River Basin and Surrounding states, yet continue to allow users into the other state pages without a password. Additional information is provided in Section 3.7, Precipitation Frequency Data Server.

Quality control continues on data from study areas to be used in the areal reduction factor (ARF) curve development, and software development to process the data and ultimately generate the ARF curves is nearly complete. The name of this project, formerly Depth Area Reduction (DAR), has been officially changed to reflect new nomenclature. Additional information is provided in Section 3.8, Areal Reduction Factors.

3. Progress in this Reporting Period

3.1 Peer Review

The Hydrometeorological Design Studies Center (HDSC) conducted a peer review of the point and spatially interpolated precipitation frequency estimates for the Ohio River Basin and Surrounding States during the period August 15, 2003 to September 14, 2003. The review included the point precipitation frequency estimates and associated confidence intervals for all durations (5-minute to 60-day) and all return frequencies (2-year to 1000-year). The review also included the spatially interpolated grids for the following:

1. 1-hour mean annual maximum maps ("index flood" maps)
2. 1-hour 100-year precipitation frequency maps
3. 24-hour mean annual maximum maps ("index flood" maps)
4. 24-hour 100-year precipitation frequency maps

HDSC requested comments from nearly 200 individuals and received comments from 27 individuals or groups. There were 82 individual comments submitted. After parsing all of the comments, we found 53 unique comments that required a response. The separate official response was distributed on October 6, 2003 and may be found on our website (http://www.nws.noaa.gov/oh/hdsc/index.html). The most reported issue pertained to the "islands" or "bull's eyes" on the 100-year maps.

3.2 Data Quality Control

We found inconsistencies in the annual maximum series in a number of cases and developed new quality control software to test for the problem. The problem manifests itself as an annual maximum of a shorter duration that is greater than longer durations in a given year. This can happen when the data has too many missing values immediately adjacent to the accumulation period of the shorter duration for the accumulation of the longer duration to be acceptable. In these cases we were rejecting the accumulation completely rather than accepting the shorter duration accumulation as a minimum value for the longer duration. It can also happen when average adjustment factors that account for different sampling intervals are applied (e.g. 24-hour vs. 1-day data.)

The new annual maximum consistency check identifies occurrences where shorter duration annual maxima are higher than longer duration annual maxima. If the difference is small (<10%), the longer duration annual maxima was set equal to the shorter duration for that year. Differences of 10% or more were flagged and will be examined more closely for data quality issues. The 10% cutoff was chosen as a convenient indicator above which the cause is generally missing data.

3.3 L-moment Analysis

After correcting data at some stations, L-moments were re-run for 24-hour and longer durations. The heterogeneity factors (H1) for each region and each longer duration (2-day to 60-day) were tabulated. A check of regions with H1>2, which indicates heterogeneity, was conducted. Regions 9, 14, 20, 21, 22, 23, 24, 26, 32, 33, 35, 36, 42, 46, 47, 52, and 55 regions had at least one heterogeneous longer duration. In each of these 17 cases, the heterogeneity could be attributed to one or two stations that were driving the H1 statistic for each duration. The data at each of these stations was checked again for data quality. In 13 cases, the stations did not significantly influence the final quantiles (<3% difference when the station is excluded). These cases are acceptable regardless of H1>2. In 3 cases, bad data was found and corrected.

The 60-minute regionalization is complete yielding 25 hourly regions (figure 2). Table 1 shows the number of hourly stations in each of the new hourly regions. The 25 hourly regions were checked for shorter duration (2-hour to 12-hour) heterogeneity. Only regions 7, 11 and 24 had heterogeneity at any shorter durations. In each of these cases, the heterogeneity could be attributed to one or two stations that were driving the H1 statistic for each duration. The data at each of these stations was checked again and found to be OK. These cases are acceptable regardless of H1>2, since removing the station(s) did not appreciably change the quantiles (<2.5% difference in all cases).

Table 1: Number of stations in new 25 hourly regions based on 60-minute data.

region	**# stns**
1	25
2	17
3	55
4	40
5	9
6	27
7	29
8	79
9	19
10	9
11	25
12	11
13	131
14	36
15	61
16	12
17	63
18	4
19	107
20	26
21	14
22	23
23	71
24	64
25	8

3.4 Best-Fitting Distributions

Sensitivity testing was conducted to determine the best-fitting distribution for the 24-hour data. Particular attention was paid to:

1. whether the spatial distribution of the region-based best-fitting distribution is geographically consistent or homogenous
2. whether the spatial distribution of the region-based best-fitting distribution is explicable by climatology
3. whether the impact on 100-year estimates of changing the best-fitting distribution is within 2 - 3%
4. whether selecting a different distribution results in 1,000-year estimates that are less than an observed maximum at a station.

After sensitivity testing, GEV was selected for 58 regions; Generalized Normal (GNO) for 10; Generalized Logistic (GLO) for 12. Table 2 lists the selected distributions for the 24-hour duration.

Best-fitting distributions were tabulated based on the results of 3 tests (Xtest, Realdata, RMSE) for all 80 daily regions for selected longer durations. We decided use the distribution selected for 24-hour data to longer durations in each region for the following reasons:

1. 24-hour is the most reliable analysis
2. Each duration will be consistent with the next in a given region
3. Preliminary sensitivity testing has already demonstrated the viability of this approach.

A full sensitivity study will be conducted to verify the results.

The 3 daily at-site stations were extensively tested for best-fitting distribution. These stations produce results that are inconsistent with the regional approach and require special treatment. For at-site A1, which is comprised of 1 daily (11-6610) and 2 hourly (11-6610H, 12-1626H) stations, GEV was the best-fitting distribution for 1-day through 60-day. For at-site A2 (11-3335), GLO was selected for 1-day through 4-day and GEV was selected for 7-day through 60-day. For at-site A3 (22-1880), GEV was selected for 1-day through 60-day.

Best-fitting durations were tabulated for the 60-minute data. After sensitivity testing, GEV was the best fit for 18 regions; GNO for 6 regions; GLO for 1 region. We decided to use the GEV distribution for all hourly durations in all regions for the following reasons:

1. The majority of regions indicated GEV
2. Each duration is then consistent with the next in a given region for all shorter durations
3. Sensitivity testing has already demonstrated the viability of this approach.

Table 2: Best-fitting distributions selected for all longer durations based on 24-hour.

Region	24-hr Overall	**24-hr after sensitivity testing**
1	GEV	**GEV**
2	GEV	**GEV**
3	GEV	**GEV**
4	GNO	**GNO**
5	GEV	**GEV**
6	GEV	**GEV**
7	GNO	**GEV**
8	GNO	**GEV**
9	GNO	**GEV**
10	GNO	**GNO**
11	GNO	**GNO**
12	GLO	**GLO**
13	GEV	**GEV**
14	GNO	**GNO**
15	GEV	**GEV**
16	GLO	**GLO**
17	GEV	**GEV**
18	GEV	**GEV**
19	GNO	**GEV**
20	GLO	**GLO**
21	GEV	**GEV**
22	GLO	**GLO**
23	GEV	**GEV**
24	GNO	**GNO**
25	GNO	**GEV**
26	GNO	**GEV**
27	GEV	**GEV**
28	PE3	**GNO**
29	GEV	**GEV**
30	GEV	**GEV**
31	GEV	**GEV**
32	GEV	**GEV**
33	GLO	**GEV**
34	GNO	**GEV**
35	GEV	**GEV**
36	GNO	**GEV**
37	GNO	**GEV**
38	GNO	**GEV**
39	GEV	**GEV**
40	GLO	**GLO**
41	GNO	**GEV**
42	GLO	**GLO**
43	GEV	**GEV**
44	GLO	**GLO**
45	GNO	**GEV**
46	GEV	**GEV**
47	GNO	**GEV**
48	GEV	**GEV**
49	GLO	**GEV**
50	GLO	**GEV**
51	GEV	**GEV**
52	GEV	**GEV**
53	GNO	**GEV**
54	GLO	**GLO**
55	GEV	**GEV**
56	GLO	**GLO**
57	GNO	**GEV**
58	GNO	**GEV**
59	GLO	**GLO**
60	GEV	**GEV**
61	GNO	**GEV**
62	GEV	**GEV**
63	GEV	**GEV**
64	GEV	**GEV**
65	GEV	**GEV**
66	GEV	**GEV**
67	PE3	**GNO**
68	GNO	**GNO**
69	GLO	**GLO**
70	GNO	**GEV**
71	GLO	**GLO**
72	GNO	**GEV**
73	GEV	**GEV**
74	PE3	**GNO**
75	GEV	**GEV**
76	GEV/GNO	**GEV**
77	GEV	**GEV**
78	GNO	**GNO**
79	GEV	**GEV**
80	GNO	**GEV**

3.5 Software Updates

Software that automates the adjustment procedure that ensures consistency from shorter durations through longer durations for co-located stations was modified to accommodate the use of different distributions for different regions. Once completed the hourly regions were re-run with the appropriate co-located adjustments executed.

Software was written to accommodate the different n-minute ratios for the 2 general n-minute regions of the Ohio project area (northern and southern). This software applies the appropriate ratio when populating the PFDS to convert 60-min estimates at hourly stations to n-minute estimates.

Software was written to conduct an annual maxima consistency check (see Section 3.2 Data Quality Control). This software documents cases where a shorter duration is greater than a longer duration for further investigation. Software has also been written to automatically adjust annual maxima in the time series after the investigation is complete.

Software was written to check for intersite dependency by computing cross-correlation between stations. The software identifies cases where stations within 50 miles of each other have appreciable cross-correlation in annual maxima occurring at the same time.

3.6 Spatial Interpolation

In preparation for the peer review, draft 100-year 24-hour grid and 100-year 60-minute cartographic maps were created for each state. Otherwise, no spatial interpolation activities occurred.

3.7 Precipitation Frequency Data Server (PFDS)

We modified the Precipitation Frequency Data Server in our continuing effort to make it more user friendly. The modifications include:

a) a greater density of grid lines on the graphs to assist in picking values from the graph,

b) When point estimates are requested for a location by selecting a specific observing location, the station name now appears in the downloadable text table.

We also re-arranged the web pages used for selecting bulk data for downloading. The pages are designed to provide access to huge volumes of data, including spatial (GIS) data, in a clear and organized manner.

State-specific password protected web pages were developed to allow peer reviewers to evaluate the draft precipitation frequency estimates for the Ohio River Basin and Surrounding states, yet continue to allow users into the other state pages without a password. At the conclusion of the peer review, the state-specific web pages, that once provided access to draft data, were replaced with a general web page acknowledging that updated data will be available soon.

3.8 Areal Reduction Factors

The name of this project, formerly Depth Area Reduction (DAR), has been officially changed to reflect new nomenclature. Progress continues in the development of geographically-fixed Areal Reduction Factor (ARF) curves for area sizes of 10 to 400 square miles. We have successfully completed testing and evaluation of the software through Chapter 5 of TR-24 by looking at the statistical results for Chicago, IL data. We are now working on the remaining chapters.

We have completed quality control on the data for Chicago, IL; Walnut Gulch, AZ; Tifton, GA; North Danville, VT; and Hastings, NE. Quality control work is continuing on the remaining study areas. We have added Riverside, CA and Maricopa, AZ to the list of areas we are studying. It is anticipated that a total of 15 study areas throughout the United States will be used in the study. The set of ARF curves developed for each study area will be tested for differences to determine if a single set of ARF curves can be used for the entire U.S. as is the case today or whether separate curves for different regions of the country are more appropriate.

4. Issues

No issues.

5. Projected Schedule and Remaining Tasks

The following list provides a tentative schedule with completion dates. Brief descriptions of tasks being worked on next quarter are also included in this section.

Data Collection and Quality Control [Complete]
Temporal Distributions of Extreme Rainfall [Complete]
L-Moment Analysis/Frequency Distribution [November 2003]
Peer Review of Spatially Distributed Point Estimates [Complete]
Spatial Interpolation [December 2003]
Precipitation Frequency Maps [December 2003]
Web Publication [January 2004]
Spatial Relations (Areal Reduction Factors) [December 2003]

5.1 Data Quality Control

All annual maxima time series will be corrected for inconsistencies between durations for given years. Cross-correlation between stations will also be checked.

5.2 L-Moment Analysis

After the annual maxima check, L-moments will be re-run for all daily regions. Sensitivity testing of the best-fitting distribution for longer durations will be conducted. Longer durations will also be more closely examined to ensure that the regionalization is sufficient for those durations. During the next quarter, all L-moments and confidence limits will be completed.

5.3 Spatial Interpolation

After addressing reviewer comments, HDSC will produce and send final mean annual maxima for all durations to be interpolated by Oregon State University using PRISM.

5.4 Peer Review

Peer review comments that require further investigation will be fully addressed during the next quarter.

5.5 Temporal Distributions of Extreme Rainfall

Temporal distributions will be recomputed for the project area. Only cases that are greater than the 2-year return period at each rainfall observing station will be used in computing the temporal distributions at each duration. In addition, the temporal distribution graphs will be prepared in grayscale instead of color to improve copying on black and white copiers.

5.6 Areal Reduction Factors (ARF)

Software for the ARF computations will be completed in the next quarter and the computations will be performed for 15 areas. The resulting curves will be tested for differences to determine if a single set of ARF curves is applicable to the entire U.S. or whether curves vary by region.

References

Frederick, R.H., V.A. Myers and E.P. Auciello, 1977: Five- to 60-minute precipitation frequency for the eastern and central United States, NOAA Technical Memo. NWS HYDRO-35, Silver Spring, MD, 36 pp.

Hershfield, D.M., 1961: Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years, *Weather Bureau Technical Paper No. 40*, U.S. Weather Bureau. Washington, D.C., 115 pp.

Hosking, J.R.M. and J.R. Wallis, 1997: *Regional frequency analysis, an approach based on L-moments*, Cambridge University Press, 224 pp.

Huff, F. A., 1990: Time Distributions of Heavy Rainstorms in Illinois. Illinois State Water Survey, Champaign, 173, 17pp.

Lin, B. and L.T. Julian, 2001: Trend and shift statistics on annual maximum precipitation in the Ohio River Basin over the last century. Symposium on Precipitation Extremes: Prediction, Impacts, and Responses, 81st AMS annual meeting. Albuquerque, New Mexico.

Lin, B. and J. Vogel, 1993: A comparison of L-moments with method of moments, *Engineering Hydrology Symposium Proceedings*, ASCE, San Francisco, CA, July 25-30, 1993.

Miller, J.F., 1964: Two- to ten-day precipitation for return periods of 2 to 100 years in the contiguous United States, *Technical Paper No. 49*, U.S. Weather Bureau and U.S. Department of Agriculture, 29 pp.

Miller, J.F., R.H. Frederick and R.J. Tracy, 1973: Precipitation-frequency atlas of the western United States, *NOAA Atlas 2*, 11 vols., National Weather Service, Silver Spring, MD.

Myers, V.A. and R.M. Zehr, 1980: A Methodology for Point-to-Area Rainfall Frequency Ratios, NOAA Technical Report NWS 24, Office of Hydrology, National Weather Service, Silver Spring, MD.